Army Research Laboratory

Summary: Phase III Urban Acoustics Data

by W.C. Kirkpatrick Alberts, II, John M. Noble, and Mark A. Coleman

ARL-MR-0794 September 2011

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Army Research Laboratory
Adelphi, MD 20783-1197

ARL-MR-0794 **September 2011**

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REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)* September 2011	**2. REPORT TYPE** Data Report	**3. DATES COVERED (From - To)**
4. TITLE AND SUBTITLE Summary: Phase III Urban Acoustics Data		**5a. CONTRACT NUMBER**
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) W.C. Kirkpatrick Alberts, II, John M. Noble, and Mark A. Coleman		**5d. PROJECT NUMBER**
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory ATTN: RDRL-CIE-S 2800 Powder Mill Road Adelphi MD 20783-1197		**8. PERFORMING ORGANIZATION REPORT NUMBER** ARL-MR-0794
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		**10. SPONSOR/MONITOR'S ACRONYM(S)**
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This report briefly describes the results of Phase III of a recent experimental program to characterize the propagation of sound in the urban environment. The site studied herein represents a third fundamental case of urban acoustics: a small, isolated cluster of single-story buildings. The results include microphone recordings of both impulsive and continuous-wave sources as well as meteorological information.

15. SUBJECT TERMS

Urban acoustics

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** W. C. Kirkpatrick Alberts, II
a. REPORT Unclassified	**b. ABSTRACT** Unclassified	**c. THIS PAGE** Unclassified	UU	18	**19b. TELEPHONE NUMBER** (*Include area code*) (301) 394-2121

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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1. Introduction

Recently, a series of experiments were conducted to characterize the sound fields around what might be termed fundamental cases of urban acoustics (*1–3*) in order to determine the level of approximation that could be used when attempting to model the propagation of sound through urban terrain. The experimental study of these fundamental cases included a single-story isolated building typical of North American suburban areas and a three-story, concrete-block building similar to those found in urban industrial areas. This report describes the third phase of the study, which endeavored to characterize the sound field around an isolated set of four single-story buildings.

Section 2 briefly describes the methods and procedures used during the experiment. Section 3 presents example results, section 4 provides a short discussion of the results, and the final section offers some concluding remarks.

2. Methods and Procedures

The data referenced in this report were collected at a site in Maryland in July 2009 as part of an investigation of the processes that govern the propagation of sound through an urban environment (*1–3*). The data consist of microphone recordings of a pseudorandom noise broadcast by a loudspeaker and impulses generated by a propane bird-scare device. Collection times were 5 min for the bird-scare device and 3 min for the noise, which resulted in files of approximately 375 and 225 MB, respectively. The 32 microphones were emplaced around four single-story buildings. In addition to the microphone recordings, meteorological information (wind speed, wind direction, temperature, pressure, and humidity) was also recorded during the two test days.

Files containing the coordinates of the building corners and coordinates of all of the sensor and source positions are included with the data. Microphone calibration information, photographs of the experimental setup and two MATLAB™ scripts for viewing the data are also included. The two MATLAB viewers are attached as appendices. Appendix A gives the script for viewing microphone data and appendix B gives the script for viewing data recorded by temperature probes.

3. Results

Figures 1 through 3 show representative data from 3 of the 32 microphones. Figure 1 shows an impulse recorded by a reference microphone. Figure 2 depicts broadband noise recorded by a roof-mounted microphone. Figure 3 shows a series of impulses recorded at a point between two buildings. Figure 4 is a representative plot of the wind speed versus time as measured by an ultrasonic anemometer placed on a tripod behind one of the buildings. The final figure, figure 5, is an example of the photographs that are included in the data set.

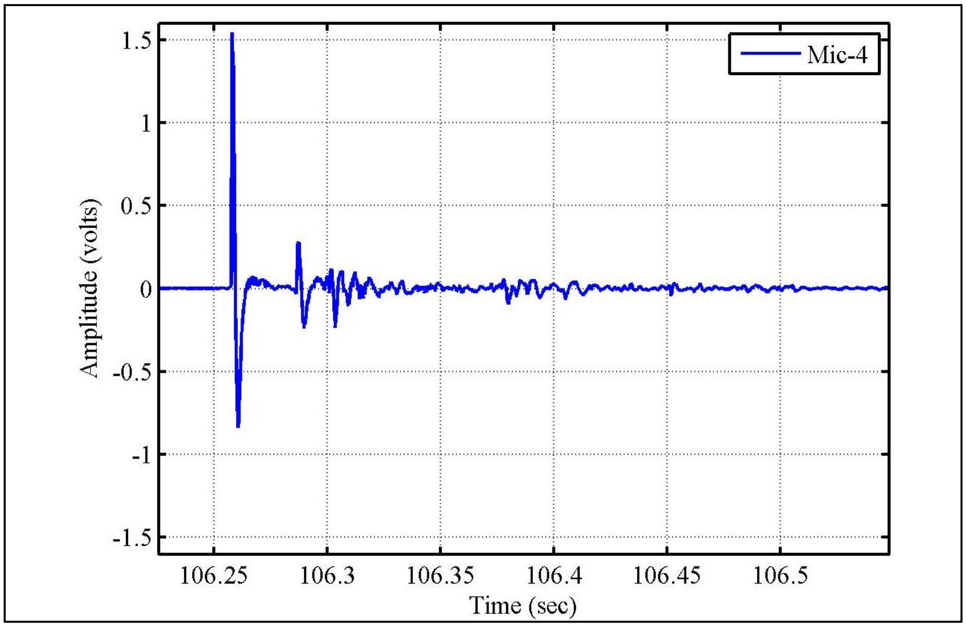

Figure 1. Reference microphone (#4) recording of an impulse generated by a bird-scare device.

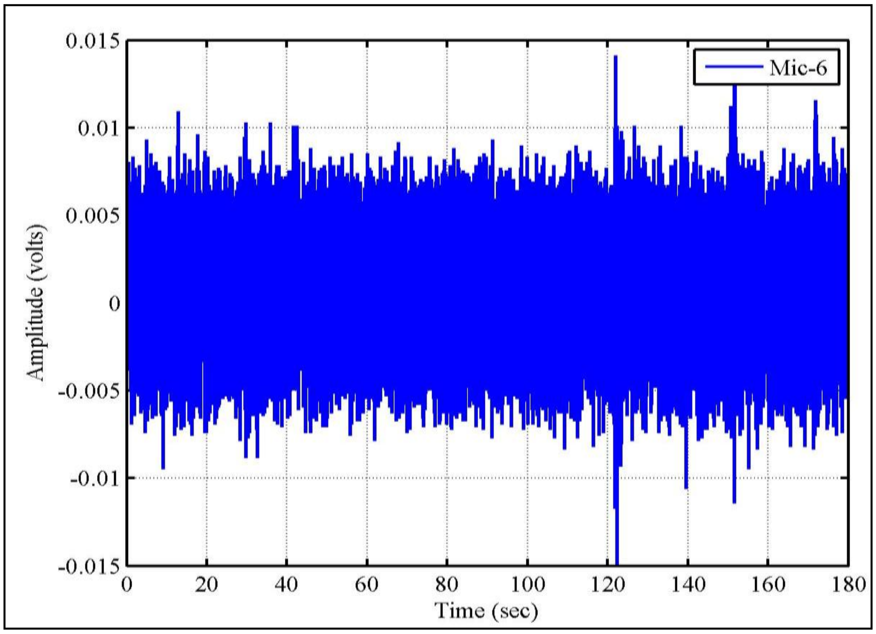

Figure 2. Roof-mounted microphone (#6) recording of broadband, pseudorandom noise generated by a loudspeaker.

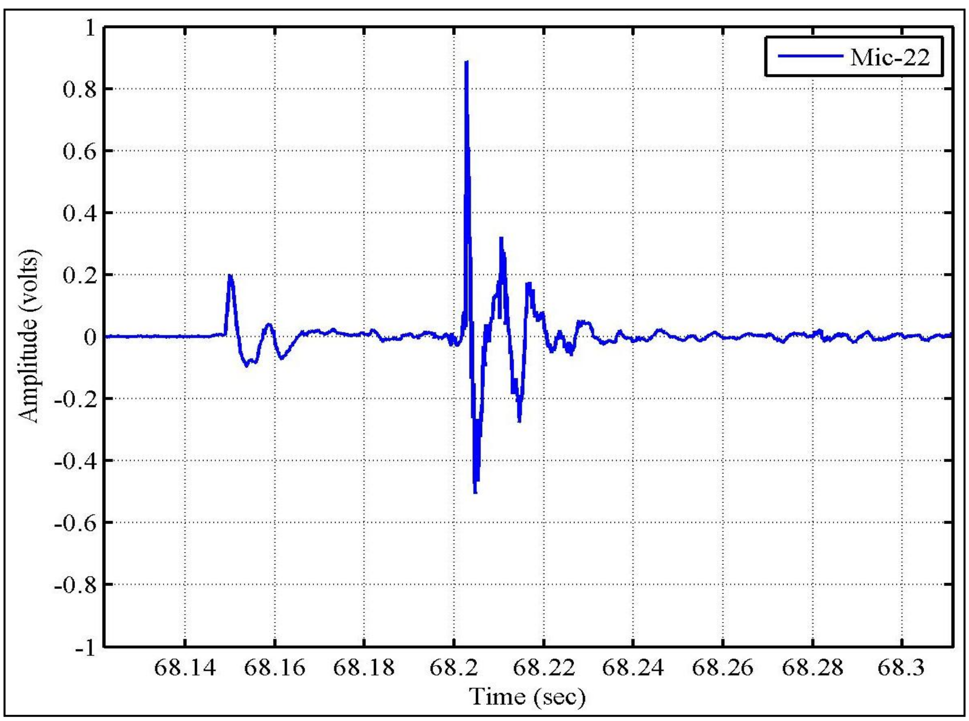

Figure 3. Bird-scare impulse as recorded by a microphone situated between two buildings (#22).

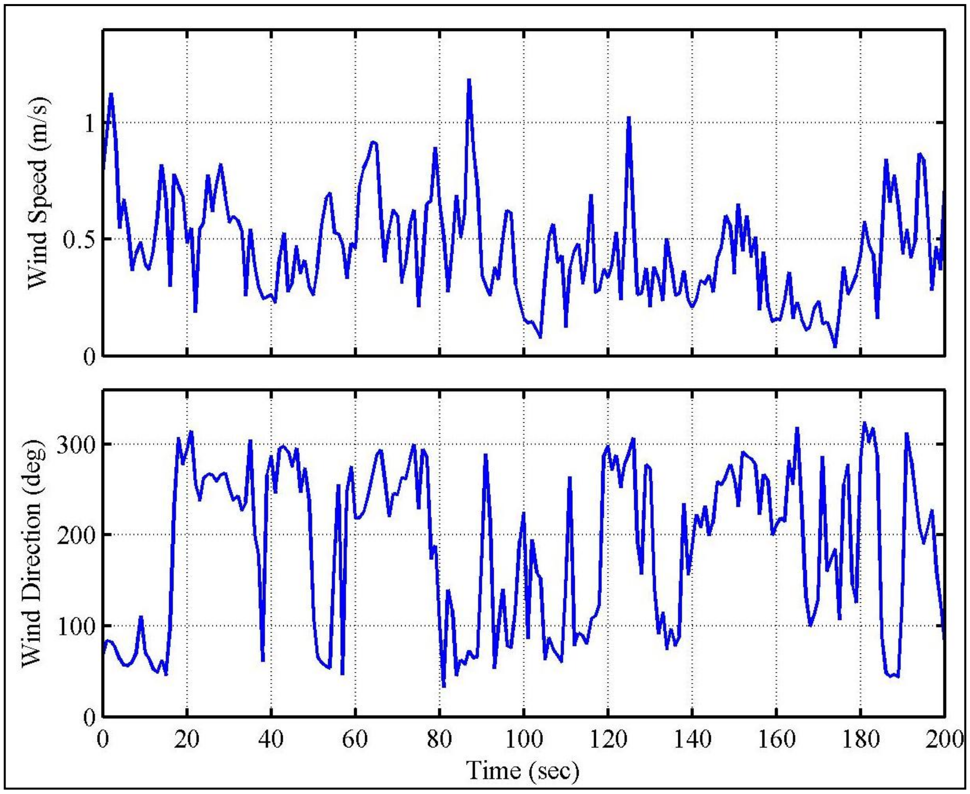

Figure 4. Wind speed and wind direction as measured by an ultrasonic anemometer in close proximity to one of the four buildings in the experiment.

Figure 5. Example photograph of the experiment site and setup.

4. Discussion

Example time-domain acoustic data are shown in figures 1 through 3. The reference impulse shown in figure 1 at 106.25 s is clean and will be time gated and used for normalizing scattered and diffracted impulses measured at other positions around the site. This impulse was measured by a microphone approximately 1 m above ground in front of the building in the center of figure 5. Figure 2 shows diffracted random noise generated by a loudspeaker superimposed with impulses (at 120, 140, and 150 s) from a nearby police firing range. The microphone that recorded the noise in figure 2 was mounted on the roof of the central building in figure 5. Thus, the noise reaching the microphone passed a single diffracting edge. Figure 3 demonstrates the difficulty associated with sound propagation in an urban environment, and shows, at 68.15 s, a strong, clear impulsive arrival and, at 68.2 s, a second strong impulsive arrival. The first arrival is a superposition of at least eight diffracted paths around the building in the far right of figure 5. The second arrival is due to a reflection from the building second from the right in figure 5. A direction-finding algorithm operating on either of the impulses in figure 3 would point in an erroneous direction. The ultrasonic anemometer data shown in figure 4 demonstrate the changes in the horizontal flow due to the wind passing over a building, which can lead to turbulent effects on propagating sound, such as increased energy penetration into the acoustic shadow of the building due to turbulent scattering. Figure 5 shows the layout of the site and allows for an approximate determination of the elevation changes encountered by a propagating acoustic impulse.

5. Conclusion

The third phase of an urban acoustics study to characterize the propagation of sound around an isolated set of four single-story buildings has generated a comprehensive acoustic data set of recordings of impulsive and broadband noise signatures at many points around the set of buildings. Included in the data set are meteorological measurements taken both close to and separated from the buildings. Initial analysis of time-domain acoustic and wind data shows complicated behavior that might be expected considering the non-trivial environment of the experiment.

6. References

1. Alberts, W.C.K., II; Noble, J. M.; Coleman, M. A. On the Application of Well-known Diffraction Models to the Sound Field in the Shadow Zone of an Isolated Building. *App. Acoust.* **2009**, *70* (8), 1128–1130.

2. Alberts, W.C.K., II; Noble, J. M.; Coleman, M. A. Sound Propagation in the Vicinity of An Isolated Building: an Experimental Investigation. *J. Acoust. Soc. Am.* **2008**, *124* (2), 733–742.

3. Alberts, W.C.K., II; Coleman, M. A.; Noble, J. M. *Fundamental Cases of Urban Acoustics and Their Interaction with Propagating sound: Phase II*; ARL-TR-5285; U.S. Army Research Laboratory: Adelphi, MD, September 2010.

Appendix A. MATLAB Microphone Data Viewer

The following is the script we used for viewing microphone data.

```
function T3_data_viewer(numchan)
%Function to view channels from each of the 32 microphones used during the
%Davidsonville, MD urban acoustics experiment.  This will also serve as an
%example for extracting the data from the rather large binary files (~400
%MB)
%
%Input
%1) number of channels to plot (1 to 5)(limited to 5 for memory reasons)
%
%Output
%1) Plot containing all requested channels
%
%initial writing -- Dr. W.C. Kirkpatrick Alberts, II: 30 March 2011

%Request file path and name from user
[fil, pat] = uigetfile('*.bin','Select Combined Data File');
patfil = strcat(pat,fil);

fid = fopen(patfil);

%Get number of points per channel(10 kHz sample rate, 4 bytes, 32 channels)
fseek(fid,0,'eof');
ppchan = ftell(fid)/4/32;
fseek(fid,0,'bof');

%Get channel numbers from user
channel = zeros(1,numchan);
lgdstr = cell(1,numchan);
for k = 1:numchan
    channel(k) = input('Enter microphone number:');
    lgdstr{k} = strcat('Mic-', num2str(channel(k)));
end

%Read data
Data = zeros(ppchan,numchan);
for k = 1:numchan
    fseek(fid,(channel(k)-1)*ppchan*4,'bof');
    Data(:,k) = fread(fid,ppchan,'float32');
end

time = 0:1e-4:(ppchan/1e4)-1e-4;
figure
hold all
for k = 1:numchan
    plot(time,Data(:,k))
        xlabel('Time (sec)')
        ylabel('Amplitude (volts)')
end
```

```
switch numchan
    case 1
        legend(lgdstr{1})
    case 2
        legend(lgdstr{1},lgdstr{2})
    case 3
        legend(lgdstr{1},lgdstr{2},lgdstr{3})
    case 4
        legend(lgdstr{1},lgdstr{2},lgdstr{3},lgdstr{4})
    case 5
        legend(lgdstr{1},lgdstr{2},lgdstr{3},lgdstr{4},lgdstr{5})
end
```

Appendix B. MATLAB Temperature Data Viewer

The following is the script we used for viewing data recorded by temperature probes.

```
function T3_temp_viewer
%Function to view temperature date from each of the 8 probes used during the
%Davidsonville, MD urban acoustics experiment.  This will also serve as an
%example for extracting the data.
%
%Input
%none
%
%Output
%1) Plot containg all requested channels
%
%initial writing -- Dr. W.C. Kirkpatrick Alberts, II: 31 March 2011

%Request file path and name from user
[fil, pat] = uigetfile('*.bin','Select Combined Data File');
patfil = strcat(pat,fil);

fid = fopen(patfil);

%Get number of points per channel(4 bytes, 8 channels)
fseek(fid,0,'eof');
ppchan = ftell(fid)/4/8;
fseek(fid,0,'bof');
numchan = 8;
channel = 1:8;
lgdstr = cell(1,numchan);
for k = 1:numchan
    lgdstr{k} = strcat('Temp-', num2str(channel(k)));
end

%Read data
Data = zeros(ppchan,numchan);
for k = 1:numchan
    fseek(fid,(channel(k)-1)*ppchan*4,'bof');
    Data(:,k) = fread(fid,ppchan,'float32');
end

time = 0:ppchan-1;
figure
hold all
for k = 1:numchan
    plot(time,Data(:,k))
        xlabel('Time (sec)')
        ylabel('Temperature (deg C)')
end
axis([0 300 20 40])
legend(lgdstr{1},lgdstr{2},lgdstr{3},lgdstr{4},lgdstr{5},...
            lgdstr{6},lgdstr{7},lgdstr{8})
```

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